Acids, Bases & Salts

Chemistry I

March 2012

Introduction

- Acids and bases are electrolytes that produce a specific type of ion in water solution.
- Acids will produce hydrogen ions, also called protons, because hydrogen ions are hydrogen atoms without the electron. This leaves the hydrogen with just a proton
- Bases are electrolytes that generally produce hydroxide ions (OH^{-1}).
- Salts are the products of an acid and a base.

Acids

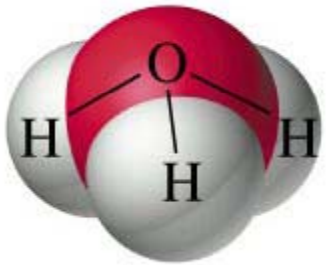
- General Properties
  - sour taste
  - contain the element hydrogen
  - some will react with metals to produce hydrogen gas
  - change the colors of acid-base indicators
  - will react with bases to form a salt and water
  - are electrolytes in water solution
    - (called aqueous)

Acids

- three definitions:

1. traditional-a chemical compound that contains hydrogen and ionizes in aqueous solution to form hydrogen ions
2. Brønsted- any ion or molecule that can donate a proton such as water
3. Lewis- is an electron-pair acceptor which also includes compounds that do not contain hydrogen

- Types of aqueous acids
  - when we have water involved and hydrogen ions produced, a new ion comes about. It is basically a hydrated hydrogen ion called an hydronium ion which looks like this:



Hydronium ion
H_3O^+

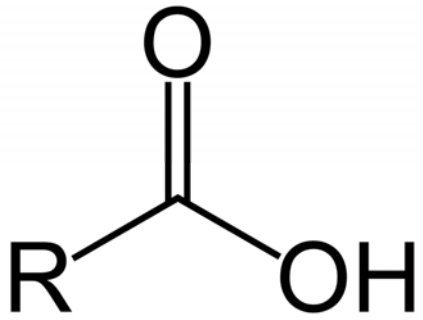
Acids

Acids

- Terms given to acids:
  - strong acid refers to a compound that is an electrolyte and dissociates 100%
    - monoprotic acids can donate one proton
      - nitric, perchloric, & hydrochloric
    - diprotic acid can donate 2 protons
      - sulfuric acid
    - polyprotic: any acid can donate more than one proton

Acids

- Weak acids are also weak electrolytes
  - examples: acetic (vinegar), phosphoric, carbonic,
- Organic acids are weak acids where most of the molecule is made of carbon & hydrogen atoms.
  - functional group called a carboxyl Looks like this:



- Names & structures of common acids
  - Binary acids - made of two elements : hydrogen & another element
    - all begin with ***hydro-***
    - name root of second element and add suffix ***-ic***
    - example : HCl-hydrochloric
  - Oxyacids- hydrogen, oxygen & a third element
    - named by adding prefix & suffix to root of third element

Acids

- Some of the oxyacids have differing amounts of oxygen.
- they are differentiated by prefixes & suffixes:
  - examples:
    - HClO **hypo**chlor**ous**
    - $HClO_2$ chlor**ous**
    - $HClO_3$ chlor**ic**
    - $HClO_4$ **per**chlor**ic**
    - HNO_3 nitr**ic**
    - HNO_2 nitr**ous**

Acids

Strong inorganic acids

Acid	Formula	What it is used for
hydrochloric	HCl	the major component of gastric acid and of wide industrial use.
Nitric	HNO_3	is used in the manufacture of explosives as well as fertilizers
Sulfuric	H_2SO_4	uses include ore processing, fertilizer manufacturing, oil refining, wastewater processing, and chemical synthesis; used in car batteries

Medium to weak inorganic acids

Acid	formula	What it is used for
Boric	H_3BO_3	used as antiseptic,insecticide, and to make other chemical compounds
Carbonic	H_2CO_3	plays a very important role in mammalian blood. Also in soda.
hydrofluoric	HF	Used to make numerous pharmaceuticals, diverse polymers (e.g. Teflon) ; able to dissolve glass
Phosphoric	H_3PO_4	may be to clean rusted iron or steel surfaces

Weak organic acids

Acid	formula	What its used for
Acetic	$HC_2H_3O_2$	table vinegar (4 to 8 percent by volume or about 5% by volume
Benzoic	$C_7H_6O_2$	are used as a food preservative and is an important for the synthesis of many other organic substances.
Butyric	$C_4H_8O_7$	found in rancid butter,parmesan cheese, and vomit. has an unpleasant odor and acrid taste
Citric	$C_6H_8O_7$	found in citrus fruits is a natural preservative is also used to add an acidic (sour) taste to foods and soft drinks

Weak Organic Acids

Acid	Formula	What it is used for
Formic	CH_2O_2	occurs naturally, most famously in the venom of bee and ant stings.
Lactic	$C_3H_6O_3$	is primarily found in sour milk products
malic	$C_4H_6O_5$	in many sour or tart foods Found in apples

Acid Anhydrides

- The word anhydride means with out water
- Acid anhydrides are:

  Nonmetal oxides that form acids when they react with water

  Ex: $CO_2 + H_2O \rightarrow H_2CO_3$

Acid Decomposition

the acid breaks down into the oxide of the nonmetal plus water.

Ex:

$$H_2SO_3 \rightarrow H_2O + SO_3$$

$$HNO_3 \rightarrow N_2O_5 + H_2O$$

$$H_3PO_4 \rightarrow P_2O_5 + H_2O$$

Bases

- General properties of bases:
  1. bases have a bitter taste
  2. dilute solutions feel slippery to the touch
  3. will change the color of a acid-base indicator
  4. bases react with acids to produce a salt and water
  5. are electrolytes
  6. will react with animal tissue

» Definitions of bases:

1. traditional- a substance that contains hydroxide ions and dissociates to produce hydroxide ions in water
    a) said to be alkaline

2. Brønsted - any molecule or ion that is a proton acceptor

3. Lewis - any molecule or ion that is an electron pair donor

Bases

Bases

- types of bases:
  - strong bases produce a lot of hydroxide ions in solution
    - the hydroxide looks like this :
      - $[OH^{-1}]$
    - these hydroxides are usually made of the Group 1 & 2 active metals that are soluble in water
  - weak bases produce small numbers of hydroxides in water such as ammonia

Strong Bases

- Strong bases dissociate 100% into the cation and OH- (hydroxide ion). The hydroxides of the Group I and Group II metals usually are considered to be strong bases.
  - **LiOH - lithium hydroxide**
  - **NaOH - sodium hydroxide**
  - **KOH - potassium hydroxide**
  - **RbOH - rubidium hydroxide**
  - **CsOH - cesium hydroxide**
- * **Ca(OH)2 - calcium hydroxide**
- * **Sr(OH)2 - strontium hydroxide**
- * **Ba(OH)2 - barium hydroxide**
- * These bases completely dissociate in solutions of 0.01 M or less. The other bases make solutions of 1.0 M and are 100% dissociated at that concentration.

- Sodium hydroxide (NaOH) or caustic soda
- Calcium hydroxide ($Ca(OH)_2$) or limewater
- Ammonium hydroxide (NH_4OH) or ammonia water
- Magnesium hydroxide ($Mg(OH)_2$) or milk of magnesia
- Many bleaches, soaps, toothpastes and cleaning agents

Strong Bases

Weak Bases

- Examples of weak bases include ammonia, NH_3, and diethylamine, $(CH_3CH_2)_2NH$.
- **Most weak bases are anions of weak acids.**
- **Weak bases do not furnish OH- ions by dissociation. Instead, they react with water to generate OH-ions.**

Basic Anhydrides

- are:
  - Metal oxides that react with water to produce a solution that contains hydroxide ions
  - Generally:

$$O^{-2} + H_2O \longrightarrow 2OH^{-1}$$

Examples:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

$$MgO + H_2O \longrightarrow Mg(OH)_2$$

Expanding the definitions

- The Brønsted-Lowry definitions for acids and bases:
- **Acids** are species that donate a proton (H^+).
- **Bases** are species that accept a proton.

- *Acid example:*
  $HNO_{3\,(aq)} + H_2O\ NO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$
- In this example, HNO_3 is an acid and H_2O is acting as a base.
  NO_3^- is called the **conjugate base** of the acid HNO_3, and H_3O^+ is the **conjugate acid** of the base H_2O.

Expanding the definitions

- *Base example:*

$$NH_{3(aq)} + H_2O \longrightarrow NH^{+}_{4(aq)} + OH^{-}$$

- In this example, NH_3 is a base and H_2O is acting as an acid. NH_4^+ is the conjugate acid of the base NH_3, and OH^- is the conjugate base of the acid H_2O.
- A compound that can act as either an acid or a base, such as the H_2O in the above examples, is called **amphiprotic**.

Conjugate acid/base pairs

- A conjugate base is:
  - what remains of an ion or molecule after it has donated a proton
  - and the ion or molecule may now accept a proton
- A conjugate acid is:
  - what remains after an ion or molecule has accepted a proton
  - and can now donate a proton

Acid	Base
HSO_4^{-1}	SO_4^{-2}
HCl	Cl^{-1}
H_3O^{+1}	H_2O

Conjugate acid/base pair examples

- Gilbert Lewis had this thing for electron pairs.
- He said that an acid is any species that can accept an electron pair.
- A base is an species that can donate an electron pair.

- Enough said!!!!!!!!!!!!!!

Lewis Acids & Bases

Neutralization Reactions

- When an acid and a base react, they will
- produce water and a salt

$$\text{acid} + \text{base} \longrightarrow \text{a salt} + H_2O$$

- In a neutralization reaction, a mole of H+ ions reacts with a mole of OH-,forming a mole of water.
- However, one mole of any acid will not necessarily neutralize one mole of base.

» The reverse of the neutralization reaction is called **hydrolysis**.

» In a hydrolysis reaction a salt reacts with water to yield the acid or base:

$$BA + H_2O \text{ --> } HA + BOH$$

reverse of the neutralization

Salts

- Salts are the non-water product of an acid base neutralization.

- There are four possible acid base reactions that produce salts. They are the reaction of a:

  1) strong acid with a strong base.
  2) weak acid with a strong base.
  3) weak base with a strong acid.
  4) weak acid with a weak base.

- 1) A salt of a strong acid and a strong base will produce a solution with pH = 7.
- 2) A salt of a weak acid and a strong base will produce a solution with pH greater than 7.
- 3) A salt of a weak base and a strong acid will produce a solution with pH less than 7.
- 4) A salt of a weak acid and a weak base produces a solution whose pH depends on the strengths of the acid and base which made the salt.

Salts and pH range in water solution

1) $HCl + NaOH \rightarrow Na^+ + Cl^- + H_2O$

2) $HC_2H_3O_2 + NaOH \rightarrow Na^+ + C_2H_3O_2^- + H_2O$

3) $NH_3 + HCl \rightarrow NH_4^+ + Cl^-$

4) $HC_2H_3O_2 + NH_3 \rightarrow NH_4^+ + C_2H_3O_2^-$

Example reactions of each are

- Power to the proton!!!!!!!!!!!!!!!!!!
- A method of determining acid/base concentration is by the pH/pOH scale.
- The scale goes 0-14 with 7 as a neutral point.

pH & pOH

» Mathematically pH & pOH are calculated by:

$pH = - \log [H^{+1}]$

the brackets [ ] mean concentration in moles per liter

$pOH = -\log [OH^{-1}]$

$pH + pOH = 14$

pH & pOH

Ways to measure pH

- The pH of a solution can be measured 2 easy ways:
  - 1. use of a pH meter
  - 2. use of some compounds that change color in the presences of hydrogen ions. These are called acid/base indicators

Acid-Base Indicators

- An acid-base indicator is a weak acid or a weak base.
- The undissociated form of the indicator is a different color than the ionic form of the indicator.
- An indicator does not change from pure acid to pure alkaline at a specific hydrogen ion concentration, but rather, color change occurs over a range of hydrogen ion concentrations.
- This range is termed the color change interval.
- This range is expressed as a pH range.

Several indicators are listed below with their pH range and color change.

Indicator	pH Range	Acid color	Base color
Thymol Blue	1.2 –2.8	red	yellow
Methyl yellow	2.9 – 4.0	red	yellow
Methyl orange	3.1 – 4.4	red	orange
Bromophenol blue	3.0 – 4.6	yellow	blue-violet
Methyl red	4.4 – 6.2	red	yellow
Bromophenol blue	6.2 – 7.6	yellow	blue
Phenol red	6.4 – 8.0	yellow	red
Thymol blue	8.0 – 9.6	yellow	blue
Phenolphthalein	8.0 – 10.0	colorless	red
Alizarin yellow	10.0 – 12.0	yellow	lilac
Diazo violet	10.1 – 12.0	yellow	violet
Nitramine	11.0 – 13.0	colorless	orange-brown
Poirrier's blue	11.0 – 13.0	blue	violet-pink
Trinitrobenzoic acid	12.0 – 13.4	colorless	orange-red

The END